REPORT DOCUMENTATION PAGE

AFRL-SR-BL-TR-00-

0598

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	1-Sep-98	Final Report: Mar 1, 1997 - Feb 23, 1998

4. TITLE AND SUBTITLE

Large Scale Electromagnetic Computation on Nonlinear Optical Systems

5. FUNDING NUMBERS

F49620-97-1-0142

6. AUTHOR(S)

J. V. Moloney

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Department of Mathematics
University of Arizona
Tucson, Arizona 85721

8. PERFORMING ORGANIZATION REPORT NUMBER

Final Report FRS 301620

9. SPONSORING /MONITORING AGENCY NAMES(S) AND ADDRESS(ES)

AFOSR/PLK
110 Duncan Avenue Rm B115
Bolling AFB, DC 20332-8050

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

The award went towards the purchase of an ONYX2 Silicon Graphics rack system with an internal graphics engine and 6 195MHz CPUs. The significantly increased computing capacity resulting from the DURIP award has enabled us to work on the following projects:

- Structure Dependence of the Linewidth Enhancement Factor: A Full Microscopic Many-body Calculation
- High Speed Current Modulation of High Power MOPA Devices
- Critical Focusing-Induced Novel Light Guides in Air
- New Classes of Vectorial Electromagnetic Light Bullets

New Projects being explored include:

- Contact to the Envelope Theories when High Nonlinear Events Stretch the Validity of These Models
- Full Vectorial Situation when the Characteristics Spatial Scales Approach the Wavelength of Light and Temporal Scales Reach a Sigle or Half Optical Cycle
- Double Clad Fiber Amplifiers and Lasers for High Brightness Applications

14. SUBJECT TERMS

15. NUMBER OF PAGES

3

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std.Z39-18
298-102

Final Report
1 Mar 97 to 28 Feb 98
F49620-97-1-0142
Large Scale Electromagnetic Computation on Nonlinear Optical Systems

Arizona Center for Mathematical Sciences
Department of Mathematics
University of Arizona
PI: J.V. Moloney

The award of $150,000 made under the DURIP '97 initiative went towards the purchase of an ONYX2 Silicon Graphics rack system with an internal graphics engine and 6 195MHz CPUs. This system was chosen as it provided state-of-the-art graphical visualization and computing capabilities and offered a cost-effective upgrade route. The in-house supercomputing engine has provided a significant boost to our AFOSR-funded research projects. The latter include the contract, "High Speed Modulation, Beam Steering and Control of Spatiotemporal Chaos in Semiconductor Lasers," (AFOSR 49200-97-1-0002), and AASERT grants, "Modelling Novel Wavelength and Ultra-Short Time-Scale Phenomena in Nonlinear Optics," (AFOSR F49620-95-1-0454); "Femtosecond Pulse Interactions with Nonlinear Interfaces," (AFOSR F49620-96-1-0311); and "Interactive Nonlinear PDE Solvers," (AFOSR F49620-97-1-0451). Our contract research is driven by large scale computation in nonlinear optics areas of direct interest to Air Force Laboratory scientists. Interactions and collaborations exist with Air Force scientists at the Semiconductor Branch, Phillips Laboratory, Kirtland AFB who are working under the High Power Semiconductor Laser Technology (HPSLT) program. Our projects provide theoretical input and simulation backup to their ongoing experimental efforts on high brightness semiconductor laser sources and the new effort on double-clad fiber amplifiers and lasers. Direct collaborations also exist with the Nonlinear Optics Group at the Phillips Laboratory. The effort here is focused on feedback-induced instabilities in multimode semiconductor lasers, synchronization of chaotic semiconductor lasers and message encoding in chaotic signals. The significantly increased computing capacity resulting from the DURIP award has enabled us to tackle the following major problems.

Structural Dependence of the Linewidth Enhancement Factor: A Full Microscopic Many-body Calculation.

Compute for the first time, the full semiconductor response function from a first-principles microscopic theory including the Quantum Well structure, the barrier and GRINSCH regions. Previously, only the semiconductor gain spectra could be computed by taking into account the Quantum Well states - this represented a major computation and that problem was only solved over one year ago. We used a semi-phenomenological approach at the time to include the barrier state contributions. The details of the structure outside the QW has a profound influence on the magnitude of the Linewidth Enhancement Factor and this latter quantity determines the strength of the filamentation instability which degrades the performance of high power semiconductor devices. Being able to control the magnitude of this factor is therefore critical to designing new generations of bandwidth-limited short pulse and/or high brightness semiconductor amplifiers and lasers. There is a direct interest in this problem at the Phillips Laboratory, as the HPSLT group are moving towards fabricating and testing high brightness sources at communications wavelengths (1.55 microns). Our accomplishments have led to consultations with laser engineers at Opto Power Corporation, a leading manufacturer of high power diodes, and with researchers at the Philips Research Optoelectronics Group in Eindhoven, The Netherlands.

High Speed Current Modulation of High Power MOPA Devices

We have been able to study, for the first time, the complicated interplay between unavoidable residual optical feedback and intensity filamentation instabilities in monolithically integrated Master Oscillator Power Amplifier Lasers. This study requires that we resolve the full space and time development of the counterpropagating electromagnetic fields and the total carrier density through this multi-section complex structure. Our major conclusion is that these devices are unlikely to be useful unless one operates the Power Amplifier current below its value for spontaneous lasing. For an output facet reflectivity, R=.05% the threshold is around 0.8 A and the output power is in the hundreds of milliwatts.

Critical Focusing-Induced Novel Light Guides in Air

Provide the capability to explore for the first time the physical mechanism that allows high power femtosecond duration laser pulses to form a self-guiding channel in air via the combined effects of critical self-focusing and weak plasma generation. This phenomenon promises important applications in lightning control, LIDAR, remote sensing and energy delivery. This problem is extremely challenging computationally as the physical phenomenon is highly explosive, involving simultaneous compression in space and time. Even with our present computational facility provide by the DURIP '97 award, we are restricted to studying radial symmetry geometries. We anticipate being able to go to full 3D+time simulations with the additional hardware provided under a recent DURIP '98 hardware augmentation award.

New Classes of Vectorial Electromagnetic Light Bullets

The computing facility has allowed us to access the fully 2D and 3D vector Maxwell ultrashort pulse regime. At the vector Maxwell level, one is forced to resolve the underlying optical carrier wave and this places a significant restriction on the type of problem that can be solved. We have made significant progress on a series of 1D and 2D problems and these results are reported under our main contract and the AASERT annual progress reports. We have also carried out a few fully 3D simulations.

Two Important Limiting Cases Are Being Explored

1. Establish a contact to the envelope theories when highly nonlinear events stretch the validity of these models. This occurs in the atmospheric propagation problem when the pulse undergoes severe space and time compression. Normally one can derive higher order perturbation corrections to the 3D NLS but this extended system will eventually not be reliable.

2. Study the full vectorial situation when the characteristic spatial scales approach the wavelength of light and temporal scales reach a single or half optical cycle. The potential exists to discover new nonlinear "soliton-like" propagating electromagnetic pulses which possess extremely low energies but enormous peak intensities. It is not known when optical breakdown comes into play for such extremely fast interactions. One can anticipate that it may not lead to irreversible damage and instead allow for possible control and utilization of the breakdown process.

Double Clad Fiber Amplifiers and Lasers for High Brightness Applications

We have begun to initiate the development of a fiber amplifier/laser model in response to the needs of the group at the Phillips Laboratory. The huge gain bandwidth of the doped fiber amplifiers and lasers, encompass thousands of longitudinal modes and leads to complex spatiotemporal behavior.